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The economic feasibility of a crop-residue densification plant: A case study for the city of Jinzhou in China

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ABSTRACT

The efficient utilization of the enormous crop-residue resources in China is crucial for providing biofuel, reducing the risk of environmental pollution, and increasing farmers' income. Examining the case of a crop-residue densification plant in the city of Jinzhou, China, this study examines the economic feasibility of this plant by analyzing raw material supply, product market, energy policy, and financial reports. The results indicate that these factors, such as the raw material supply, market, and energy policy, favor the development of densified biofuel from crop residues. The typical financial indicators were estimated as being notably positive over a 10-year timeframe, and a sensitivity analysis indicated no threats to project profit stability. These aforementioned analyses suggest that the utilization of crop residues as densified biofuel in China possesses good economic viability. If the numerous historical, industrial, geographical, and energy-related similarities are taken into account, this study can also be used to provide a feasibility evaluation methodology for crop-residue densification plants in other similar regions.

Contents

1. Introduction

Due to the vast agricultural base in China, the crop residue yield in 2010 reached approximately 850 million tons, which was calculated from the product yield of crops and the residue to crop ratio [1,2]. The utilization of crop residue mainly follows four

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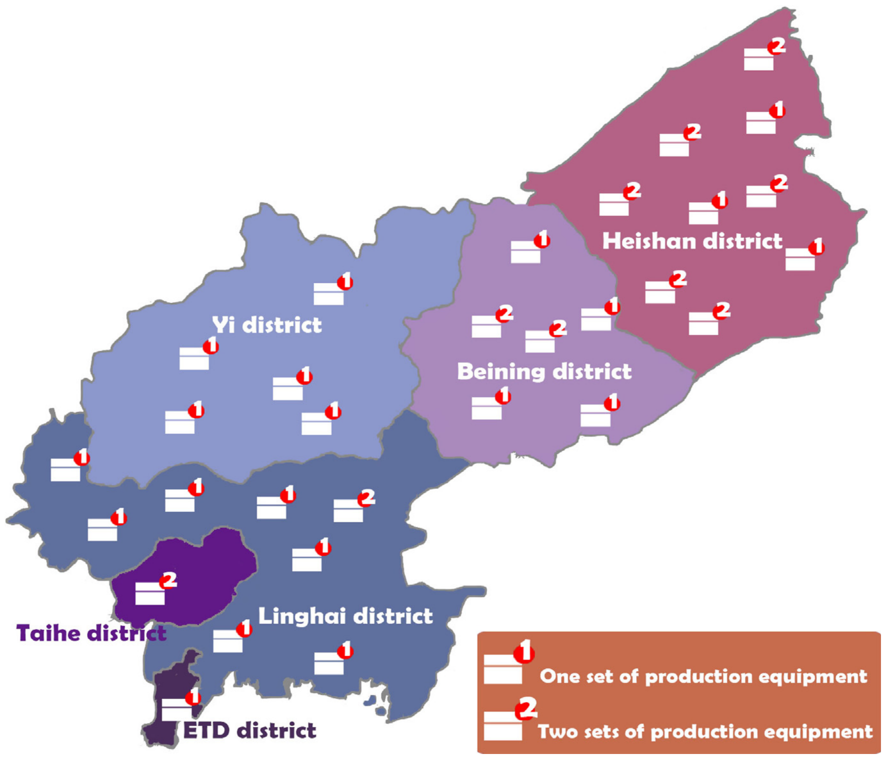

Fig. 1. The distribution of densified biofuel sub-plants in the city of Jinzhou.

routes: industrial material, fertilizer returned directly to the field, livestock feeding, and traditional energy in rural areas. The utilized amount of crop residue accounted for only approximately 70% of total yearly output, and the remaining crop residue was discarded [3]. This discarding not only wastes a resource but also poses potential risks to the environment. The main factors influencing the utilization of crop residue are poor transportation, storage, and low conversion efficiency [4].

Densification technology, which converts loose crop residue into densified biofuel, holds great promise for expediting the efficient use of crop residues [5]. First, the technology can improve the physical properties of crop residue to facilitate collection, transportation, and storage. Second, densification technology can increase energy density and subsequently produce high energy-conversion efficiency. Finally, the crop residue densified biofuel has many demand sectors, including the residential, commercial, and industrial sectors. A number of previous studies have been performed in which the main area of interest focused on the technical problems with densified biofuel, such as its densification property [6–10] and energetics characterization [11–16]. The technical feasibility of densified biofuel from crop residue in China has been presented in our previous study [17]. However, the development of a densified biofuel industry is not only related to the technical issues, but also to other issues, including raw material supply, the densified biofuel product market, finance, and energy policy. Some previous studies have evaluated the economic feasibility of the biomass of densified biofuel [18–23]. However, these previous efforts in assessing densified biofuel were performed using biomass materials of regions other than China, further research is required for evaluating the possible implementation of the biofuel in China and the characteristics of densified biofuel from crop residue. On one hand, large differences exist in the markets, financial systems, and energy policies for densified biofuel among countries, that significantly affect the economic feasibility of densified biofuel. On the other hand, the type of biomass materials is closely related with their energy performance [24], accordingly, their raw material cost and product-sold revenue. To the best of our knowledge, there is no existing study on the economic feasibility of crop-residue densification plants in China. Examining the case of a crop-residue densification plant in city of Jinzhou, China, this study analyzes the raw material supply, product market, energy policy, and financial reports of this plant and provides some measures of the economic feasibility of crop-residue densification plants in China.

Table 1
The yields of main crops and their residues in the city of Jinzhou.

Crops	Residue-to-crop ratio [a]	Yield of crops [b] (10^4 t)	Yield of crop residues (10^4 t)
Rice	0.623	22.1	13.8
Wheat	1.336	0.3	0.4
Corn	2	156.6	313.2
Soybeans	1.5	2.2	3.3
Tubers	0.5	2.3	1.2
Oil bearing	2	9.9	19.8
Total	–	193.4	351.6

[a] *Source*: MAO/DOE project [1].
[b] *Source*: Liaoning statistical yearbook 2011 [25].

2. Overview of the crop-residue densification plant

The proposed plant is located in the city of Jinzhou (longitude 121°05′E, latitude 41°04′N) in the Liaoning province of China, where there are abundant crop residues and vast energy requirements providing a potential market for the densified biofuel. The timeframe for this project is from 2012 to 2021. To build an efficient production and market network, 30 sub-plants are well-distributed based on the crop-residue yield in city of Jinzhou (Fig. 1). Every sub-plant

preferentially collects crop residues and sells densified biofuel products in Jinzhou to offset transportation costs. According to the plan, the project will expand stepwise over the first five years. In particular, the number of sets of production equipment from 2012 to 2016 is 30, 30, 36, 36, 40, respectively, and then the project scale will involve 40 sets of production equipment from 2017 to 2021. Some of the sub-plants with sufficient raw material supply will utilize two sets of production equipment. The full capacity for one set of production equipment is calculated as follows: 1 t/h × 10 h/day × 310 days/year = 3100 t/year. The yearly production amount in the first year is set to 75% capacity (= 2325 t), whereas in other years, the yearly production will reach 3100 t under full capacity.

3. Analysis of raw material supply, product market and energy policy

3.1. Raw material supply for crop-residue densified biofuel

The yield of the main crop residues in the city of Jinzhou (Table 1) is estimated to be 3.5 million tons, according to the crop yield [25] and residue to crop ratio [1]. The available amount of crop residues for densified biofuel (Q_a) can be calculated with the following equation

$$Q_a = \frac{f_r \times Q_t}{A_J} A_{sp} \tag{1}$$

where f_r is the percentage of remaining crop residue after removal for other uses and is set to a typical value of 30% [3], Q_t (= 3.5 million tons) is the total amount of crop residue in the city of Jinzhou, A_J is the total area of the city and is equal to 9891 km^2 [26], and A_{sp} is the collection area of crop residue for every sub-plant. Due to the looseness of crop residues, the transportation cost would be very high if the round-trip collection radius distance from the field to the subplot location is too large. On the other hand, the supply of raw material may be insufficient if the collection radius is too small. Considering the two situations, the optimal collection radius (r) can be estimated as follows:

$$r = \sqrt{\frac{(Q_p \times f_p/f_c)}{\pi(f_r \times Q_t/A_J)}} \tag{2}$$

where Q_p is the full capacity for one production equipment set (= 3100 t), f_p is the conversion ratio of raw material to densified biofuel and is set to 1.6:1 [27], and f_c is the collection coefficient of crop residues (= 0.6 [28]). According to Eq. (2), a value of 5.0 km for the optimal collection radius (r) was calculated, which is also comparable a value calculated by Mani et al. [29]. Then, the A_{sp} can be estimated using $\pi \times r^2 = \pi \times 5.0^2 = 78.5$ km^2.

Substituting the above parameters into Eq. (1), a Q_a value of 8376.1 t was obtained, which is enough to supply crop residue to every sub-plant.

3.2. Product market for crop-residue densified biofuel

The city of Jinzhou is one of the industrial cities in Liaoning province. The energy consumption required by large-scale industry enterprises in 2011 alone amounted to 3.75 million tons of coal equivalent (tce). In terms of the scale of this project, all the sub-plants can produce an upper limit of 0.12 million tons of densified biofuel which is equal to 62 thousand tce, according to the gross heating value of crop residues that is approximately half of that of a high-grade coal [30]. On one hand, there appears to be a promising market for densified biofuel due to the enormous energy consumption in the city of Jinzhou. However, densified biofuel will not put great pressure on the existing energy market in Jinzhou because the energy substitution rate is less than 2%. These factors favor increasing utilization of densified biofuel in the city of Jinzhou.

3.3. Energy policy for crop-residue densified biofuel

To support the efficient utilization of crop residues, some regulations and laws have been established in China. In 2005, the Renewable Energy Law of China was promulgated, which regulates the promotion, application, price management, and economic incentives of renewable energy from biomass materials [31]. The law clearly indicates that the enterprises operating gas pipeline networks and heat pipeline networks should accept biomass energy into the networks if the gas and heat produced with biomass resources conform to the gas and heat pipeline networks. In 2007, the Medium and Long-Term Development Plan for Renewable Energy in China presented the development prospective of densified biofuel as follows [32]. (a) By 2010, 500 pilot rural areas using densified biofuel will be established. The annual consumption of densified biofuel will reach 1 million tons. Densified biofuel will mainly be used as living energy for local rural residents. (b) By 2020, densified biofuel becomes a widely used form of high quality fuel and its annual consumption will reach 50 million tons. The production pattern of densified biofuel can be divided into the small scale in rural areas and large scale in suitable areas. The former will be mainly used as living energy for local rural residents, whereas the latter will be used as commercial fuel for urban residents and industrial users. In 2011, the Implementation Program of Crop-Residue Utilization during the Twelfth Five-Year Plan of China was promulgated by the National Development and Reform Commission of China, Ministry of Agriculture of China, and Ministry of Finance of China. It is clearly proposed in this program that the densified biofuel from crop residue will be developed as a priority field. In combining with new countryside construction products, crop-residue densified biofuel projects used by rural residents will be conducted, and a high-efficiency commercial operation model will be explored with the aim of large-scale application in China.

More importantly, the Interim Measures for Subsidy Management of Crop-Residue Energy Utilization were issued by the Ministry of Finance of China in 2008. Production enterprises can obtain special subsidies if they meet the following requirements: (a) the enterprise has registered capital of more than RMB 10 million (approximately 1.6 million US dollars); (b) the enterprise is in line with the local utilization plan for crop residue; (c) the crop-residue consumption amount is more than 10 thousand tons; and (d) the energy conversation product has a stable consumer base. According to this regulation, this project examined in this study can acquire subsidy income from the government with a typical subsidy income value of 100 RMB/t of densified biofuel.

4. Financial analysis

In this project, all the financial data are given in Renminbi (RMB, 1 USD = 6.24 RMB in October 2012).

4.1. Overview of investment

The initial investment for the project is estimated at 19.1 million RMB, which comes from venture capital, founder

Table 2
Overview of the initial investment.

Items	Venture capital	Founder	Bank loan
Amount (10^4 RMB)	403.12	604.69	903.60
Proportion	21.09%	31.64%	47.27%

investment, and bank loans (Table 2). Approximately 47% of the initial investment is borrowed from the bank at an annual interest rate of 6.56%. Bank loans are borrowed at the beginning of each year and paid back at the end of each year.

In 2012, the investment is mainly used for equipment/construction and the current fund, which account for approximately 53% and 47% of the total investment, respectively (Table 3). The entire current fund is supplied via bank loan, and the equipment/construction investment was raised as capital by the project. The equipment for this project mainly includes densifying machines, chipping machines, conveyance machines, and other types of auxiliary equipment. The equipment investment is approximately 48% of the equipment/construction cost, whereas approximately 52% of the equipment/construction investment is used for construction. Due to the seasonal properties of crop growth, crop residue in the city of Jinzhou is commonly harvested from October in the first year to March in the second year. The operation of a densification plant from April to September depends on the inventory of crop residues. To overcome the risks associated with variations in raw material supply, large warehouses have to be constructed to store crop residues. In addition, the bulky property of crop residues exacerbates the requirement of storage space. Hence, the construction cost for large warehouses is an important component in the equipment/construction investment.

4.2. Total revenue

As shown in Table 4, the total revenue is comprised of operating revenue and subsidy income from government. The amount of operating revenue is decided by yearly production yield and the unit price of densified biofuel. Considering the unit price of coal (approximately 1000 RMB/t coal), the unit price of densified biofuel was initially set to 650 RMB/t to improve its competitive advantage. Due to the prevailing inflation in China, the price is adjusted annually at 2007–2011 average inflation rate of 3.74% during 2007–2011[33]. The inflation rate is also applied to all the other prices such as raw material, fuel, and power. The operating revenue gradually increases with the scale expansion and the stable project operation. In 2012, the 45.3 million RMB value of the operating revenue was produced under 75% capacity conditions. Compared with 2012, the operating revenue in 2013 will be increased to 62.7 million RMB under full capacity, although there is the same number of sets of production equipment in the two years. The increase of the operating revenue in 2014 and 2016 will contribute to the expansion of project scale and the inflation rate. Finally, the operating revenue will reach a maximum value of 112.2 million RMB from 2016 to 2021. The other portion of total revenue is subsidy income from government. As previously mentioned, the government provides subsidy income in accordance with the standard of 100 RMB/t densified biofuel. Hence, the amount of subsidy income depends on annual yield. Although subsidy income is only approximately 13% of total revenue, it favors profit accumulation especially in the initial project period.

4.3. Total expenditure

The expenditure is divided into variable cost, fixed cost, and business tax/surcharge (Table 5). The variable cost mainly includes the expenses for raw material and fuel/power, whereas the fixed cost consists of manufacturing expenses, selling expenses, administrative expenses, and financial expenses. First, most of the expenditures increase in the first five years due to project expansion and later remain stable or decrease slightly in the following five years. Second,

Table 3
Investment usage statement for 2012–2021 (unit: 10^4 RMB).

Items	2012	2013	2014	2015	2016	2017–2021	Total
A. Project capital	1007.81	248.41	287.53	–	191.69	–	1735.43
A.1 For equipment and construction	1007.81	–	88.80	–	59.20	–	1155.81
A.1.1 Equipment	488.40	–	88.80	–	59.20	–	636.40
A.1.1.1 Briquetting machine	445.50		81		54		580.5
A.1.1.1.1 Feeding conveyance machine	52.80		9.6		6.4		68.8
A.1.1.1.2 Compression unit	168.30		30.6		20.4		219.3
A.1.1.1.3 Discharging machine	39.60		7.2		4.8		51.6
A.1.1.1.4 Control cabinet	89.10		16.2		10.8		116.1
A.1.1.1.5 Weighing machine	26.40		4.8		3.2		34.4
A.1.1.1.6 Strapping machine	69.30		12.6		8.4		90.3
A.1.1.2 Rubbing and breaking machine	42.90		7.8		5.2		55.9
A.1.2 Construction	519.41	–	–	–	–	–	519.41
A.1.2.1 Production workshop	263.35						263.35
A.1.2.2 Warehouse	181.29						181.29
A.1.2.3 Office	74.77						74.77
A.2 For current fund	–	248.41	198.73	–	132.49	–	579.63
B. Debt capital	903.60	–	–	–	–	–	903.60
B.1 For equipment and construction	–	–	–	–	–	–	–
B.2 For current fund	903.60	–	–	–	–	–	903.60
Total	1911.41	248.41	287.53	–	–	–	2639.03

Table 4
Total revenue (unit: 10^4 RMB).

Items	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
A. Operating revenue	4533.75	6271.08	7806.75	8098.72	9,335.12	9,684.26	10,046.45	10,422.18	10,811.97	11,216.34
A.1 Price of densified biofuel (RMB/t)	0.065	0.067	0.070	0.073	0.075	0.078	0.081	0.084	0.087	0.090
A.2 Quantity of densified biofuel (t)	69,750	93,000	111,600	111,600	124,000	124,000	124,000	124,000	124,000	124,000
B. Subsidy income	697.50	930.00	1116.00	1116.00	1,240.00	1,240.00	1,240.00	1,240.00	1,240.00	1,240.00
Total revenue	5231.25	7201.08	8922.75	9214.72	10,575.12	10,924.26	11,286.45	11,662.18	12,051.97	12,456.34

Table 5
Total expenditure (unit: 10^4 RMB).

Items	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
A. Variable cost	3309.68	4492.56	5490.24	5593.10	6333.12	6456.13	6583.74	6716.11	6853.44	6995.92
A.1 Cost for raw material	2804.65	3794.00	4620.61	4690.95	5293.25	5377.36	5464.62	5555.14	5649.05	5746.48
A.2 Cost for fuel and power	502.2	694.64	864.75	897.09	1034.04	1072.72	1112.84	1154.46	1197.63	1242.43
A.3 Impairment loss on asset	2.83	3.92	4.88	5.06	5.83	6.05	6.28	6.51	6.76	7.01
B. Fixed cost	1568.23	1676.36	1786.23	1792.95	1881.55	1886.07	1907.81	1930.35	1953.74	1978.00
B.1 Manufacturing expenses	401.13	401.13	409.56	409.56	415.19	415.18	415.19	415.19	415.19	415.19
B.2 Selling expenses	372.42	476.72	568.86	585.13	659.31	679.89	701.62	724.16	747.55	771.81
B.3 Administrative expenses	735.4	735.34	748.53	738.98	747.77	731.72	731.72	731.72	731.72	731.72
B.4 Financial expenses	59.28	63.16	59.28	59.28	59.28	59.28	59.28	59.28	59.28	59.28
C. Business tax/surcharge	30.77	43.11	54.33	57.02	66.46	69.67	73.01	76.47	80.06	83.79
Total expenditure	4908.68	6212.03	7330.80	7443.07	8281.13	8411.87	8564.56	8722.93	8887.24	9057.71

Table 6
Balance sheet (unit: 10^4 RMB).

Items	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
A. Total asset	2461.08	3315.23	4605.26	5947.55	7741.13	9641.61	11,699.84	13,921.72	16,313.35	18,881.10
A.1 Current assets	1562.09	2525.07	3843.57	5292.32	7138.79	9134.94	11,288.83	13,606.37	16,093.67	18,757.08
A.1.1 Cumulative net cash flow	501.83	1086.26	2077.03	3475.96	5067.66	7004.24	9,096.32	11,349.74	13,770.53	16,364.93
A.1.2 Net value of accounts receivable	563.89	779.97	970.96	1,007.28	1,161.06	1,204.48	1,249.53	1,296.26	13,44.74	13,95.03
A.1.2.1 Accounts receivable	566.72	783.89	975.84	1012.34	1166.89	1210.53	1,255.81	1,302.77	1,351.50	1,402.04
A.1.2.2 Allowance for bad debt	2.83	3.92	4.88	5.06	5.83	6.05	6.28	6.51	6.76	7.01
A.1.3 Inventory	496.38	658.85	795.57	809.08	910.07	926.22	942.98	960.37	978.40	997.11
A.2 Net value of fixed assets	846.25	750.60	735.32	642.04	602.34	506.68	411.01	315.35	219.68	124.02
A.2.1 Original value of fixed assets	941.89	846.25	839.40	735.32	701.24	602.34	506.68	411.01	315.35	219.68
A2.2 Accumulated depreciation	95.64	95.64	104.08	93.28	98.90	95.66	95.66	95.66	95.66	95.66
A.3 Intangibles assets	52.74	39.55	26.37	13.18	–	–	–	–	–	–
B. Liability and owners' equity	2,461.08	3,315.23	4,605.26	5,947.55	7,741.13	9641.61	11,699.84	13,921.72	16,313.35	18,881.10
B.1 Liability	1211.34	1321.58	1414.71	1424.60	1493.90	1505.72	1,517.99	1,530.72	1,543.93	1,557.63
B.1.1 Current liabilities	1211.34	1321.58	1414.71	1424.60	1493.90	1505.72	1517.99	1,530.72	1,543.93	1557.63
B.1.1.1 Short-term loans	903.60	903.60	903.60	903.60	903.60	903.60	903.60	903.60	903.60	903.60
B.1.1.2 Accounts payable	307.74	417.98	511.11	521.00	590.30	602.12	614.39	627.12	640.33	654.03
B.1.2 Long-term loans	–	–	–	–	–	–	–	–	–	–
B.2 Owners' equity	1249.73	1993.64	3190.55	4522.94	6247.23	8,135.89	10,181.85	12,390.99	14,769.43	17,323.48
B.2.1 Paid-in capital	1007.81	1007.81	1007.81	1007.81	1007.81	1007.81	1,007.81	1,007.81	1,007.81	1,007.81
B.2.2 Surplus reserve	36.29	147.88	327.41	527.27	785.91	1069.21	1,376.11	1,707.48	2,064.24	2,447.35
B.2.3 Undistributed profit	205.64	837.96	1855.33	2987.86	4453.51	6058.87	7,797.94	9,675.71	11,697.37	13,868.32

the variable cost plays a dominant proportion in the total expenditure, followed by fixed cost and business tax/surcharge. It is interesting to note that the proportion of variable cost increase from 67.4% in 2012 to 77.2% in 2021, whereas that of fixed cost decrease from 31.9% in 2012 to 21.8% in 2021. This suggests that additional expenditures are used to raw material and fuel/power. Considering that raw material accounts for more than 80% of variable cost, it can be inferred that the project expenditure will be very sensitive to the price of raw material, which will be detailed in the following section.

4.4. Balance sheet

The balance sheet is incorporated to represent the asset, liability, and solvency of the project under such scenarios (Table 6). The total asset primarily includes current assets, fixed assets, and intangible assets. The current assets comprise the cumulative net cash flow in the cash flow, the net value of accounts receivable, and the value of the densified biofuel inventory. The net value of accounts receivable is calculated by deducting 0.5% of the value of account receivable as allowance for bad debt. The current asset value rapidly increases during the project period. In 2016, current assets accounts for more than 90% of the total assets, and particularly cash, as the most liquid asset also contributes to approximately 70% of current assets. This is one important indicator of the good short-term solvency of the project. Fixed assets primarily comprise of the construction projects, machine equipment, electrical equipment, office furniture, and other depreciable items. The depreciation is calculated using a straight-line method. The construction projects and machine equipment are, respectively, depreciated over a 20-year and 10-year lifespan with a 5% salvage value. The electrical equipment and office furniture are, respectively, depreciated over a 3-year and 5-year lifespan with no salvage value. According to the accumulated depreciation and original value of the fixed assets, the net value of fixed asset can be easily derived. Intangible assets mainly refer to the training expenses of employee during the project preparation period. The proportion of liability in the liability/owners' equity during the project period decreases from approximately 50% in 2012 to 8% in 2021, which indicates the improvement of long-term solvency.

Some important financial indicators such as current ratio (current asset/current liability), quick ratio [(current asset-inventory)/current liability], liability/asset ratio (liability/total asset), and total asset turnover (operating revenue/total asset) are also derived from balance sheet data and shown in Fig. 2. The current and quick ratio increases during the project period and their values from 2013 are, respectively, above 1.5 and 1, which indicates great liquidity for this project and strong capability against short-term liability. The value of the liability/asset ratio decreases from 0.49 in the first year to 0.19 in the fifth year. This indicates that the project also has good capability against long-term liability. Due to the unstable operation and high investment in the early period of the project, the value of the total asset turnover increases and reaches a peak value of 2.17 in 2013. With the increase of reserved profit over the project period, the total asset turnover begins

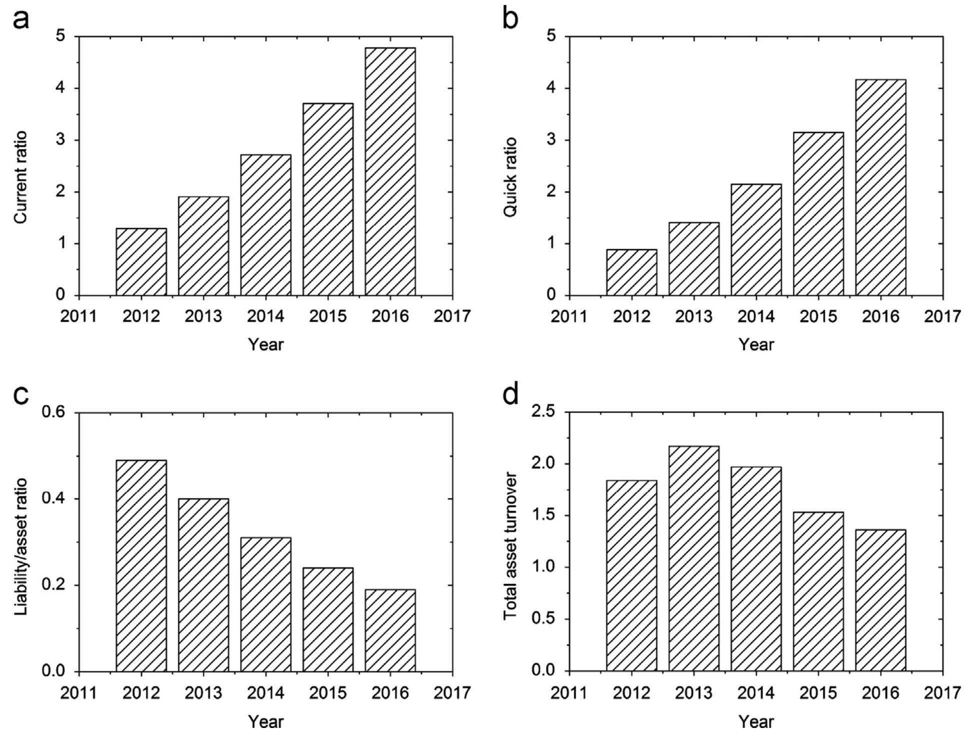

Fig. 2. The analysis of the (a) current ratio, (b) quick ratio, (c) liability/asset ratio, and (d) total asset turnover over the first five years.

Table 7
Income statement (unit: 10^4 RMB).

Items	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
A. Revenue	5231.25	7201.08	8,922.75	9,214.72	10,575.12	10,924.26	11,286.45	11,662.18	12,051.97	12,456.34
A.1 Operating revenue	4533.75	6271.08	7,806.75	8,098.72	9,335.12	9,684.26	10,046.45	10,422.18	10,811.97	11,216.34
A.2 Subsidy income	697.50	930.00	1116.00	1116.00	1,240.00	1,240.00	1,240.00	1,240.00	1,240.00	1,240.00
B. Cost of goods sold	3707.98	3707.98	4889.78	5894.92	5,997.61	6,742.48	6,865.27	6,992.65	7,124.80	7,261.88
C. Operating expenses	1200.70	1319.43	1431.95	1440.58	1,533.59	1,540.77	1,565.85	1,591.86	1,618.85	1,646.85
C.1 Business tax and surcharges	30.77	43.11	54.33	57.02	66.46	69.67	73.01	76.47	80.06	83.79
C.2 Selling expenses	372.42	476.72	568.86	585.13	659.31	679.89	701.62	724.16	747.55	771.81
C.3 Administrative expenses	735.4	735.34	748.53	738.98	747.77	731.72	731.72	731.72	731.72	731.72
C.4 Financial expenses	59.28	59.28	59.28	59.28	59.28	59.28	59.28	59.28	59.28	59.28
C.5 Impairment losses on assets	2.83	1.09	0.96	0.18	0.77	0.22	0.23	0.23	0.24	0.25
D. Income										
D.1 Income before income tax	322.57	991.88	1595.87	1776.53	2,299.05	2,518.21	2,727.95	2,945.53	3,171.24	3,405.40
D.2 Income tax	80.64	247.97	398.97	444.13	574.76	629.55	681.99	736.38	792.81	851.35
D.3 Net income	241.92	743.91	1196.90	1332.40	1,724.29	1,888.66	2,045.96	2,209.14	2,378.43	2,554.05

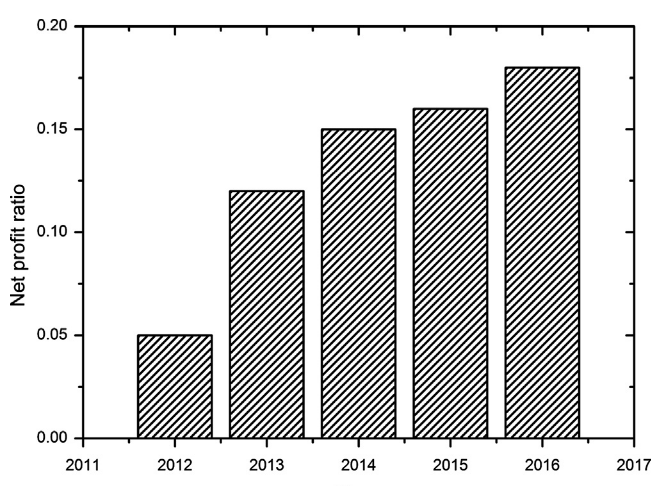

Fig. 3. The analysis of net profit ratio over the first five years.

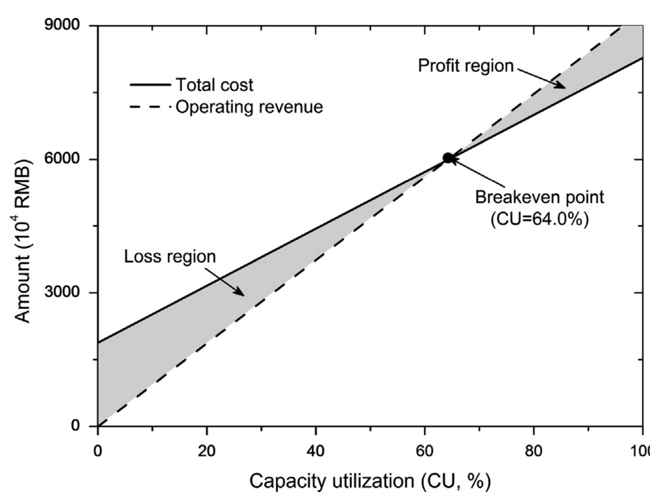

Fig. 4. Breakeven point analysis.

Table 8
Cash flow (unit: 10^4 RMB).

Items	0	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
A. Net cash flow from operating activity		−342.49	647.59	1,138.85	1,458.20	1,710.18	1,995.85	2,151.36	2,312.69	2,480.06	2,653.68
A.1 Cash inflow		5,435.27	8050.00	10,057.93	10,555.00	12,007.54	12,526.94	12,949.07	13,386.99	13,841.29	14,312.57
A.2 Cash outflow		5,777.76	7402.41	8,919.08	9,096.80	10,297.36	10,531.09	10,797.71	11,074.29	11,361.23	11,658.89
B. Net cash flow from investing activity		−1007.81	–	−88.80	–	−59.20	–	–	–	–	–
B.1 Cash inflow		–	–	–	–	–	–	–	–	–	–
B.2 Cash outflow		1007.81	–	88.80	–	59.20	–	–	–	–	–
C. Net cash flow from financial activity		1852.13	−63.16	−59.28	−59.28	−59.28	−59.28	−59.28	−59.28	−59.28	−59.28
C.1 Cash inflow		1911.41	903.60	903.60	903.60	903.60	903.60	903.60	9,03.60	903.60	903.60
C.1.1 Proceeds from investment		1007.81	–	–	–	–	–	–	–	–	–
C.1.2 Proceeds from borrowing		903.60	903.60	903.60	903.60	903.60	903.60	903.60	903.60	903.60	903.60
C.2 Cash outflow		59.28	966.76	962.88	962.88	962.88	962.88	962.88	962.88	962.88	962.88
C.2.1 Payment to settle debt		59.28	966.76	962.88	962.88	962.88	962.88	962.88	962.88	962.88	962.88
D. Net cash flow (A+B+C)		501.83	584.43	990.78	1,398.93	1,591.70	1936.57	2,092.09	2,253.42	2,420.78	2,594.41
E. Initial investment	1911.41	–	–	–	–	–	–	–	–	–	–
F. Accumulation factor (Discount factor=10%)		1.10	1.21	1.33	1.46	1.61	1.77	1.95	2.14	2.36	2.59
G. Discounted net cash flow		456.21	483.00	744.39	955.49	988.32	1,093.14	1073.57	1051.24	1,026.65	1,000.26
H. Cumulative amount of discounted cumulative net cash flow	−1911.41	−1455.20	−972.20	−227.82	727.67	1,715.99	2,809.14	3882.71	4933.94	5,960.59	6,960.85
I. NPV	6960.85										
J. Pay-back period	3.24										

to decrease from 2014 and is down to 1.36 by 2016. It can be concluded the project has great utilization efficiency of all assets.

4.5. Income statement

The income statement clearly indicates that the net income of the project increases annually and is always above zero (Table 7). It is also interesting to note that an operating loss would occur in the first and second years without government subsidy income. However, the project from the third year has good profitability and can still operate smoothly if the subsidy policy from the government changes. The net profit ratio can be calculated as the ratio of the net income to the operating revenue as shown in Fig. 3. A rising trend of net profit ration is evident. The net profit ratio closely relates to the operating revenue. When the value of the operating revenue increases from 45.3 million RMB in 2012 to 78.1 million RMB in 2014, the net profit ratio is improved from 0.05 to 0.18 during 2012–2016. To determine the breakeven point, the data in 2016 is taken as a representative year because of the maximum capacity utilization (Fig. 4). The results indicate that the value of the breakeven point for this project is 64%. In other words, the project will be profitable when its capacity utilization is greater than 64%. Approximately a 36% surplus of capacity utilization can effectively address market risk.

4.6. Cash flow

The cash flow of the project is shown in Table 8. The net cash flow of the project is always above zero and increases yearly to a peak value of 25.9 million RMB. According to the cash flow data, two important financial indicators, such as the pay-back period (PB) and net present value (NPV), can be derived. The PB is defined as the period required for the project to repay the investment outlay and is an indicator of investment return time. Apparently, low PB value, corresponding to the rapid return of the investment, will be expected for the investors. In this project, the cut-off value of PB is set to the project period (10 years) and thus the project investment can be returned in the project period. The NPV is a financial index that plays a key role in making decisions for long-term investment projects. A positive and high NPV value indicates strong project profitability and is more likely to sustain the business. The NPV can be calculated by the following equation

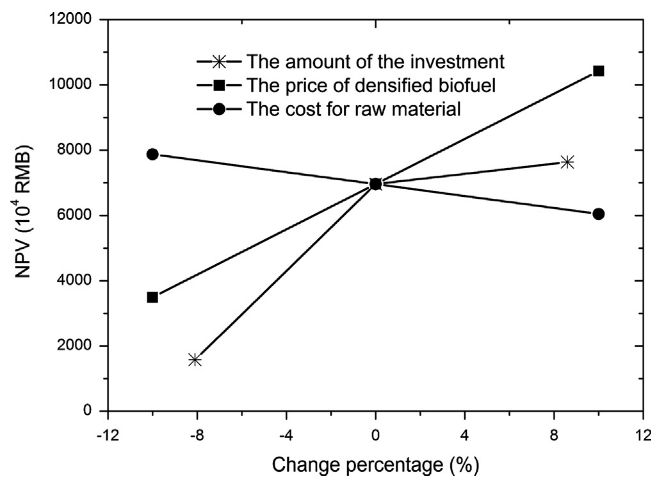

Fig. 5. Sensitivity analysis of NPV with the amount of total investment, the cost for raw materials, and the price of densified biofuel.

$$\mathrm{NPV} = \sum_{n=1}^{N}\left(\frac{\mathrm{NCF}_n}{(1+k)^n}\right) - \mathrm{INV} \tag{3}$$

where NCF_n is the net cash flow of the nth year and calculated as aggregate data regarding all cash inflows minus all cash outflows from operating, investing and financial activities; INV is the initial investment equal to 19.1 million RMB; k is the discount factor and is set to 10% according to similar biomass-based fuel projects [34,35].

The results of PB and NPV in this project are listed in Table 8. The cut-off values of PB and NPV in the eliminating criteria of this project are 10 years and 0 RMB, respectively. It is evident that the two financial indicator values are superior to their cut-off values (PB: 3.24 years < 10 years, NPV: 69.6 million RMB > 0 RMB). In particular, the positive and high NPV value suggests this project is a highly profitable business. As these indicators are dependent on project parameters such as the amount of total investment, the cost for raw material, and the price of densified biofuel, a sensitivity analysis was performed to determine how changes in these parameters affect the NPV of the project.

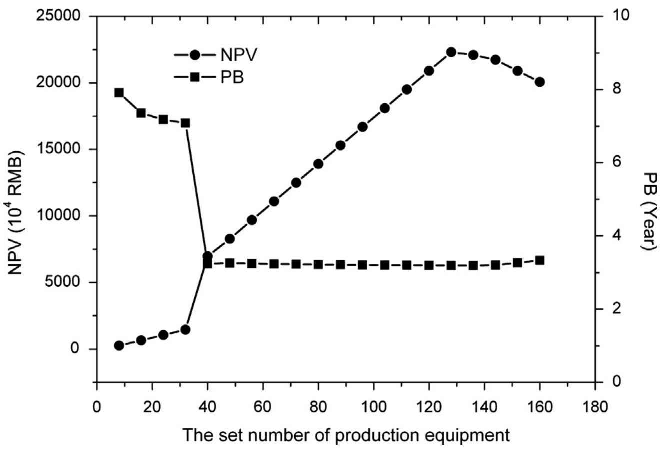

Fig. 6. The influence of plant scale on the NPV and PB parameters.

4.7. Sensitivity analysis

A sensitivity analysis of the NPV with reference to the amount of total investment, the cost for raw material, and the price of densified biofuel was performed. The amount of total investment was related to the number of production equipment. The case considered 36, 40 and 44 sets of production equipment, which correspond to total investment amounts of 17.6 million, 19.1 million, and 20.8 million, respectively, to produce the sensitivity analysis of total investment in the change percentage of approximately −8% to +8%. For the cost for raw material and the price of densified biofuel, their change percentages were set to the range of −10% to +10%. The results of the sensitivity analysis are summarized in Fig. 5. The project under all the variation ranges of these parameters produced the NPV values of above zero, which suggests profit stability for this project. The effect extent of each parameter can be visualized by the slope of the line for each parameter, i.e. the steeper the slope of the line is, the more sensitive the NPV is to that factor. Fig. 5 clearly indicates that the change in the amount of total investment produces a noticeable fluctuation in the NPV obtained, especially a change from −8% to 0. This may contribute, at a project scale of 36 sets of production equipment, to losses of the subsidy income from the government if the registered capital cannot meet the requirements of special subsidy system.

The current case study is also sensitive to change in the price of densified biofuel. Based on price fluctuations, the NPV fluctuates from 35.0 million RMB to 104.3 million RMB. This parameter presents a steep increase in NPV as the price of densified biofuel is increased. The price of densified biofuel directly decides the project operating revenue which represents more than 85% of the total revenue. Compared with the unit price of coal (1000 RMB/t), the 650 RMB/t price of densified biofuel is considerably superior. Therefore, the risk of NPV decrease due to the reduction of biofuel price is very limited.

The cost for raw material reduces the NPV of the project if there is a 10% increase of raw material cost and increases the project profit if there is a 10% decrease of raw material cost. Because the raw material cost represents such a major component of the total expenditure, minor changes in raw material cost have important influence on the profitability of the business. The raw material cost primarily includes straw purchase cost and delivery cost. To control the risks associated with variations in raw material cost, the following strategies are applied. First, a warehouse for raw material is built to stabilize straw price fluctuation caused by crop seasonable production. Second, most of the straw is provided by long-term straw supply contracts with local farmers. Third, the collection radius of straw is optimized to minimize straw transportation cost. In the current case study, the collection radius is limited to 5.0 km.

The influence of plant scale was also analyzed, and that analysis is presented in Fig. 6. This analysis indicates that due to the subsidy income the NPV and PB values at 40 sets of production equipment are drastically improved compared with the values at smaller project scales. In addition, the NPV and PB parameters are increasingly superior in accordance with increases of plant scale until reaching 128 sets of production equipment. When the plant scale is larger than 128 sets of production equipment, the NPV value decreases, and the PB value increases. These results are attributable to shortages of raw material supply.

5. Comparison with other cases

Several cases for evaluating the development of a densified biofuel industry focused on lignocellulosic biomass in other countries were also studied. Sultana et al. [36] determined the minimum production cost and optimum plant size for densification plants in western Canada using agricultural biomass residue from wheat, barley and oats. The sensitivity analyses indicated that the total cost of densified biofuel production was most sensitive to field cost followed by transportation cost. Mani et al. [29] proposed an engineering economic analysis of biomass densified biofuel in north America. It was determined that the raw material cost was the largest cost element of total densified biofuel production cost followed by personnel cost, drying cost, and pelleting mill cost. Furthermore, the scale of the densification plant also had a significant influence on the production cost. Giacomo and Taglieri [37] presented an economic analysis of a densification plant in Italy using woody residues of vineyards and olive-groves. A profitability index of 0.9, NPV value of 0.9 million Euros, and a PB value of 4 were obtained at the fixed-capital investment scale of 1 million Euros. The sensitivity analysis indicated that the profitability of the plant was especially sensitive to changes to the price of the densified biofuel, the cost of collected biomass, and the cost of the collected biomass transportation.

Although it is difficult to directly compare the current case to the aforementioned cases due to the differences in biomass type and region, several common points can be traced. The development of a densified biofuel industry using lignocellulosic biomass presents good feasibility in different countries. However, the profitability of the densified biofuel industry is very sensitive to the cost of raw material, the price of the produced densified biofuel, the cost of the collected biomass transportation, and the scale of production capacity.

6. Conclusions

The current case study for the economic feasibility of a crop-residue densification plant located in the city of Jinzhou in Liaoning province, China has been investigated. The raw material supply analysis indicates the sufficiency of crop residue supplies, as demonstrated by the finding that the yearly biofuel yield is approximately 30% of the available crop residues after removing residue involved in other utilization routes. The market analysis of the densified biofuel of interest also indicates the promising results, as the energy substitution rate is less than 2%. All of the typical financial indicators are estimated as being notably positive for a 10-year timeframe, and the sensitivity analysis indicates no threats to project profit stability. All these aforementioned analyses suggest good project viability. If the numerous historical, industrial, geographical, and energy-related similarities are considered, this study

can also be used to provide a feasibility evaluation methodology for crop-residue densification plant in other similar regions.

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